B. N. MANDAL UNIVERSITY MADHEPURA

SYNOPSIS FOR Ph. D. DEGREE IN PHYSICS

FACULTY OF SCIENCE

1. TITLE OF THE RESEARCH

ANALYTICAL STUDY OF ANTENNA: NEAR-FIELD PREDICTION WITH APPLICATION TO THE UNIFORM THEORY OF DIFFRACTION (UTD)

2. WORK PLAN

a. Purpose and Need of the Study

Electromagnetic (EM) antennas are characterized by different spatial regions such as the immediate neighborhood of the antenna (near-field) and the more distant region from the antenna (far-field). Accurate modeling of the near-field is important for many modern applications such as compact antenna arrays, multiple-element systems, wearable antennas, near-field scanning/measurements, electromagnetic compatibility (EMC) tests and deployment of systems in constrained geometries as for example on platforms, structures, vehicles etc. Conventional techniques for field prediction—full-wave methods (like Method of Moments, Finite Element Method, FDTD) or physical optics (PO) approximations—often become computationally expensive. They also lose accuracy in complex scenarios with multiple scatterers especially when electrically-large structures or discontinuities are involved.

The Uniform Theory of Diffraction (UTD) is a high-frequency asymptotic technique originally developed to extend geometrical optics (GO) and the Geometrical theory of Diffraction (GTD) so as to provide smooth field predictions including diffraction around edges, corners, and wedges. The UTD has been widely applied in far-field scattering and propagation as for example urban propagation, building/obstacle diffraction. It has comparatively less documented application specifically in modelling the antenna near-field region. Yet the near-field region is significant where reactive fields, coupling, and structured boundary conditions exist. The accurate prediction in this region can lead to improved antenna placement, coupling mitigation, near-field measurement analytics and design of compact systems.

Thus there is a clear need to study how UTD can be adapted, validated, and applied for near-field prediction around antennas and antenna platforms. The

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purpose of this study is therefore to investigate the viability of UTD for near-field antenna field modeling. The key reasons for motivating the study include the following aspects:

It makes the reduction of computational cost compared to full-wave methods for electrically large problems. It enables the modelling of antennas mounted on large platforms with edges/corners etc. It enhances the near-field prediction capability for measurement setups, near-field scanning, coupling analysis and antenna placement in constrained spaces.

The UTD is used for propagation and scattering, its application to antenna near-fields remains underdeveloped in literature, especially in combination with hybrid modelling and validation.

Hence, the study aims to formulate a methodology to apply UTD in antenna near-field zones, verify its accuracy via comparison with full-wave or measurement, delineate its domain of validity, and propose guidelines for its use in antenna engineering.

b. Details of the Project with Chapterization

The proposed chapter-by-chapter layout for the synopsis is as given:

Chapter 1: It includes the Introduction where the background on antenna fields such as near-field, transition region, far-field; definitions, importance of near-field modelling will be studied. The overview of high-frequency asymptotic methods such as GO, GTD, UTD will be made. Research objectives, scope, and contributions of the study will also be described.

Chapter 2: Literature Review

Here review of near-field modelling methods will be studied. The full-wave methods (MoM, FEM, FDTD), hybrid methods and measurement-based approaches will also be studied. The historical development; the fundamental formulations of UTD and canonical problems such as edge, wedge, corner will also be studied. The applications of UTD in scattering, antenna placement will also be topic of study.

Chapter 3: Theoretical Framework

In this part of the thesis the mathematical formulation of UTD such as basis in ray-optics, transition regions, edge and wedge diffraction coefficients,

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uniformization to avoid singularities at shadow boundaries will be described. The derivation of fields for canonical diffracting geometries such as knife-edge, wedge, and corner as used in UTD will be described.

Chapter 4: Methodology and Experimental Setup

In this section of the thesis the description of case study such as an antenna mounted near a metallic platform with edges, or a near-field scanning scenario and the specification of geometry, frequencies, antenna parameters, platform/edge geometry will be made.

Chapter 5: Results and Discussion

In this part of the thesis the presentation of results such as the near-field maps predicted via UTD vs reference; magnitude and phase comparison; error plots as a function of distance/angle/frequency will be made.

Chapter 6: Conclusions and Future Work

In this section of the thesis the summary of the key findings such as UTD applied for near-field antenna predictions beyond a given region will be mentioned.

Future work such as extension to more complex geometries for curved surfaces, multiple edges, hybrid full-wave and UTD will be described.

c. Methodology

This study will employ an analytical-numerical methodology combining the Uniform Theory of Diffraction (UTD) with validation via full-wave simulation and optionally measurement. The steps may be taken as follows:

In the beginning the problem geometry and antenna scenario will be defined.

An antenna will be selected and placed near a conducting structure/edge or platform which creates diffracting edges/wedges. The observation region for near-field will be defined. The frequency of interest will be determined. The diffracting elements will be identified and the Ray-trace rays from source to observation points via UTD will be prepared. At each observation point we find total field (E-field magnitude and phase). For near-field, we may also consider reactive fields and coupling—though UTD by itself is asymptotic and does not capture strongly

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We will investigate how these parameters impact UTD accuracy. Using the parametric results, we may determine rule-of-thumb for applying UTD in antenna near-field. Finally we will provide recommended methodology for antenna near-field prediction using UTD. We will also discuss limitations and propose future improvements regarding extension to curved surfaces, inclusion of reactive coupling, and integration with measurement systems.

d. References

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I testify that I am in a position to devote time for this research work and undertake to complete this research work within specified maximum time limit.

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Full signature of the research scholar with date

The candidate has undertaken to complete the research work under my supervision and guidance under the time limit.

Anil kumar
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Full signature of the supervisor

with date, designation, and address

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